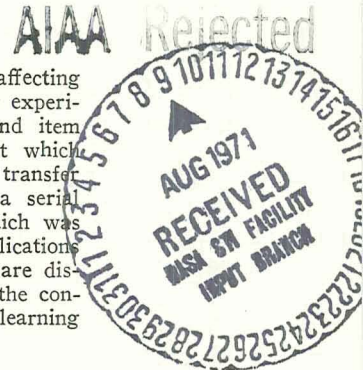# SERIAL TO PAIRED-ASSOCIATE LEARNING:
UTILIZATION OF SERIAL INFORMATION [1]

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The present experiment investigated the influence of several factors affecting transfer from serial to paired-associate (PA) learning. The major experimental variables were degree of serial training (three levels) and item frequency (three levels). The results indicated a transfer effect which ranged from positive transfer with low-frequency items to negative transfer with high-frequency items. In addition, there was evidence of a serial position effect for the experimental pairs in the transfer task which was directly related to their positions in the prior serial list. The implications of these findings for associative accounts of serial to PA transfer are discussed. Difficulties arising from associative accounts necessitated the consideration of alternate hypotheses concerning the nature of serial learning and the utilization of serially acquired information.

One of the perplexing theoretical problems for association theory is the difficulty in demonstrating transfer from serial to paired-associate (PA) tasks involving the same items. This difficulty is perplexing not only because it seems to contradict a theoretical viewpoint established long ago by Ebbinghaus, but also because it seems to contradict the obvious (cf. Young, 1968). That is, if S learns A-B-C-D-E, etc., in a serial list, should he not find it easy to learn A-B, C-D, etc., in a PA list? Although the answer would seem to be in the affirmative, it turns out empirically that such transfer occurs only under rather specialized conditions, as when S is given explicit instructions concerning the nature of the transfer task (Postman & Stark, 1967; Stark, 1968) or when the anticipation interval in the transfer task is relatively long (Heaps, Greene, & Cheney, 1968). Further, if associations in the series, A-B-C-D-E, are learned by S in *some* fashion during n trials,

should not these associations be stronger after $n + k$ trials? It would appear so, yet the one study cited by Young (1968) that has investigated this variable indicated that there was no differential effect of training on transfer (Young, 1962, Exp. Ia). Finally, if A-B-C-D-E is an experimental series of common words as opposed to a series of nonsense items, would not one expect variations in transfer as a function of such differences in meaningfulness? This would appear to be true on the basis of common sense, since meaningfulness has generally been regarded as an important factor in learning and retention and, hence, transfer. It might also be true on a theoretical basis, since one version of interference theory (Underwood & Postman, 1960) suggests that serial associations are more likely with low- than with high-meaningful materials (Underwood, 1963). This last point is especially interesting when it is realized that Ebbinghaus typically used relatively low-meaningful materials, while contemporary investigators have tended to use more meaningful materials (cf. Young, 1968). Although Stark (1968) sampled the meaningfulness dimension, she did not employ materials as low in frequency as those used by Ebbinghaus; and the range of values she did sample was not sufficient to produce differences in the rate of serial learning.

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Although the empirical points enumerated previously might be used in formulating a critical indictment of both common sense and theoretical tradition, they also clearly indicate the necessity of a parametric analysis of the joint effects of meaningfulness and degree of prior serial learning—a basic determinant of associative strength—for a more detailed understanding of the implication of transfer failures for associative theory. This would seem to be true whether associative interpretations are cast in the tradition of Ebbinghaus, e.g., the "chaining" hypothesis, in modified versions of that tradition, e.g., the "ordinal position" hypothesis, or in combinations of the two (cf. Young, 1968). Such an analysis, then, was the major goal of the present experiment.

METHOD

Design.—The basic design involved a serial to PA transfer situation, in which each S learned a 13-item serial list followed by a 12-pair PA list composed of 6 single function pairs derived from the serial list and 6 control pairs.

The materials employed varied in frequency according to Thorndike-Lorge (1944) word counts, although any given S was exposed only to items of homogeneous frequency. The median G count values for the three frequency levels used (L, M, and H) were 0 (two-syllable paralogs), 13 (two-syllable nouns), and 75 (two-syllable nouns). At each frequency level, two serial lists of approximately zero interitem associative strength were constructed. Two sets of six single function pairs were derived from each of the 13-item serial lists. One set was obtained by starting with the first item and taking only single function pairs, and the second set was obtained in a similar fashion by starting with the second item of the serial list.

Four PA lists were constructed at each frequency level. Each PA list was composed of one set of six pairs from each of the two serial lists, employed at a particular frequency level. For any given S, this resulted in a PA list composed of six pairs derived from the serial list S had learned (E pairs) and six pairs derived from a second serial list of comparable item frequency (C pairs). Across all Ss at a given frequency level, each pair of items served as either an E or C pair an equal number of times, and the various pairs were matched in terms of their relative position (1–6) within the serial list from which they were derived.

Within each frequency level, degree of training on the serial list was employed as a between-Ss variable. The three levels of training were: (a) 50% learning—the trial on which seven items were

correctly given the first time; (b) 100% learning—a criterion of one errorless trial; and (c) 150% learning—a criterion of one errorless trial plus half of the trials required to reach that criterion. In addition to these variations, a fourth group of Ss was run at each frequency level to which no serial training was given. These latter groups were not included in the main analysis of the results.

Subjects.—A total of 192 introductory psychology students served as Ss in the present experiment. Sixteen Ss were randomly assigned to each combination of training level and frequency. This resulted in a total of 144 Ss for the main experiment and 48 Ss for the groups run without serial training. Within each of these conditions, the 16 Ss were randomly assigned to the four PA lists in blocks of 2 Ss per list.

Procedure and apparatus.—The stimulus materials were presented by means of a Kodak Carousel slide projector on a rear view projection screen. The stimuli were prepared in capital letters. When Ss arrived for the experiment, they were seated in front of a table on which the screen was located, and the instructions for the experiment were presented. Standard instructions for serial and PA learning were given prior to the appropriate phases of the experiment. The Ss were not informed of the relationship between the serial and PA lists. At the beginning of the serial list, three zeros appeared on the screen followed by the 13 items in serial order. Each item was presented for 2 sec. (including the zeros) and there was a 4-sec. intertrial interval. During PA learning by the anticipation method, a 2:2-sec. rate of presentation was employed with a 4-sec. intertrial interval. When each S completed serial training to the specified criterion, he was shifted to the PA list which was learned to a criterion of one errorless trial.

RESULTS

Serial learning.—The results of serial learning were analyzed for the number of trials required to reach the 50% learning criterion. This analysis showed a significant effect for frequency, $F (2, 135) = 27.81$, $p < .001$, with the means being 6.46 for H, 7.14 for M, and 9.04 for L. No other effects approached significance. Therefore, the three groups within each frequency level appeared to be comparable in learning speed. It also should be noted that the trials required to reach the 150%, 100%, and 50% criterion, respectively, were 26.06, 17.90, and 7.23.

Paired-associate learning.—In order to provide a basis for evaluating previously reported discrepancies between early-trial
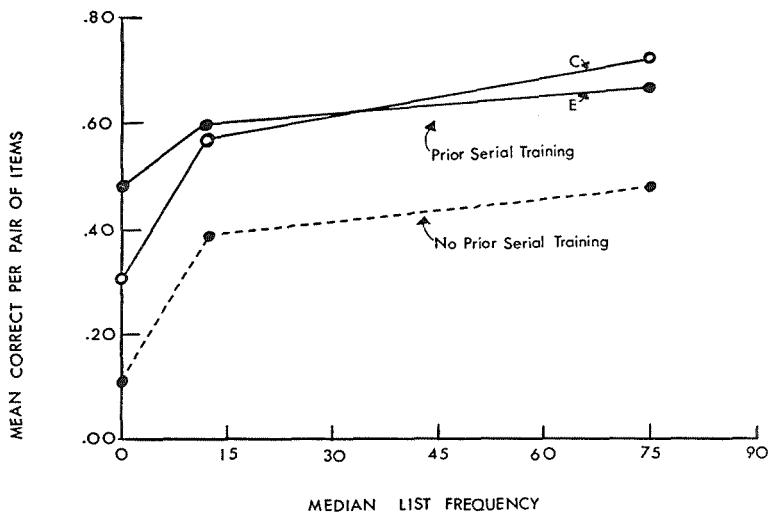
FIG. 1. Mean correct per pair for combinations of frequency by E/C pairs
and by prior serial training on Trials 1–5.

and trials-to-criterion measures, three different dependent variables were employed. (a) The main analysis of PA learning involved a fixed-trials analysis for the first five trials. The dependent variable employed for this analysis was the mean correct per S, per pair, per trial.[3] The independent variables were frequency, degree of training, trials, E vs. C pairs, and relative position of the pairs within the serial list from which they were derived. (b) A trials-to-criterion analysis was used in which the dependent variable was the trial on which all six pairs in a given subset (E or C) were first given correctly. (c) A modified trials-to-criterion analysis was made in which the dependent variable was the first trial on which any four of the six pairs in a given subset (E or C) were given correctly. For both of the trials-to-criterion analyses, the independent variables were frequency, degree of training, and E vs. C pairs.

Transfer effects.—The mean number of correct anticipations for fixed trials was .58 for E pairs and .54 for C pairs. This advantage for the E pairs was significant, F

[3] Only two Ss—one in H 150% and one in H 100%—reached criterion in less than five trials. For these Ss, the score for Trial 5 was assumed to be the same as for Trial 4 (their criterion trial) in the fixed trials analysis.

$(1, 135) = 8.38$, $p < .005$, indicating positive transfer over the first five trials. Comparable results were obtained for the modified trials-to-criterion analysis, F $(1, 135)$ $= 14.43$, $p < .001$, where the means for E and C pairs were 4.50 and 5.32, respectively. However, performance on the C pairs ($\bar{X} = 8.39$) was superior to performance on the E pairs ($\bar{X} = 9.13$), with the regular trials-to-criterion measure, F $(1, 135) = 6.79$, $p < .01$, indicating overall negative transfer. In general, this pattern of results appears to be consistent with Young's (1959; 1961) finding of initial positive transfer which gradually reduces to no transfer as criterion learning is reached.

Frequency and transfer.—For the fixed-trials analysis, the means for the L, M, and H levels of frequency were .40, .58, and .70, respectively. This result was significant, F $(2, 135) = 36.95$, well beyond the .001 level of significance. Comparable findings were obtained for both trials-to-criterion measures. While the effect of frequency was to be expected (cf. Underwood and Schulz, 1960), the Frequency × E vs. C Pairs interaction was of greater importance in the present study. The data relevant to this interaction for fixed trials are presented in Fig. 1. As Fig. 1 suggests, the interaction was significant, F $(2, 135) =$

16.95, $p < .001$. Subsequent analyses of these findings for each frequency level indicated significant positive transfer for L materials, F $(1, 45) = 45.26$, $p < .001$, no transfer for M materials, F $(1, 45) = .90$, and significant negative transfer for H materials, F $(1, 45) = 5.27$, $p < .01$. These findings were also replicated in the modified trials-to-criterion analysis. A somewhat different pattern obtains for the regular trials-to-criterion analysis in that there is negative transfer at all frequency levels (see Table 1), but the degree of transfer only attains statistical significance for high-frequency materials, t $(47) = 2.73$, $p < .05$.

The general pattern of results for the Frequency $\times$ E-C Pairs interaction suggests that empirical discrepancies with respect to the sign and statistical significance of such transfer may be due, in part, to discrepancies across various studies in the frequency (meaningfulness) values of the materials employed. For example, estimates of the frequency values used in the majority of previous experiments range from Thorndike-Lorge (1944) G count values of about 10–50 (cf. Young, 1968; Stark, 1968). If the results shown in Fig. 1 can be con-

TABLE 1

MEAN TRIALS TO THE 6/6 CRITERION FOR FREQUENCY BY E/C PAIR COMBINATIONS

Frequency	E pairs	C pairs
High	6.88	5.56
Medium	8.38	7.50
Low	12.15	12.10

sidered valid, it would not be difficult to understand the previously reported discrepancies in sign and statistical significance of transfer studies.

Serial position and transfer.—The fixed-trials analysis indicated that the main effect of the relative positions of pairs within the serial list from which they were derived was significant, F $(5, 675) = 16.68$, $p < .001$. The means for Relative Positions 1–6 were .62, .59, .52, .47, .53, and .64, respectively. Although these results appear to reflect the same bowed pattern as obtained in serial acquisition, they are not nearly as important as the data concerning the E-C Pairs $\times$ Serial Position interaction which also attained statistical significance, F $(5, 675) = 9.83$, $p < .001$. The data relevant to this interaction are presented in
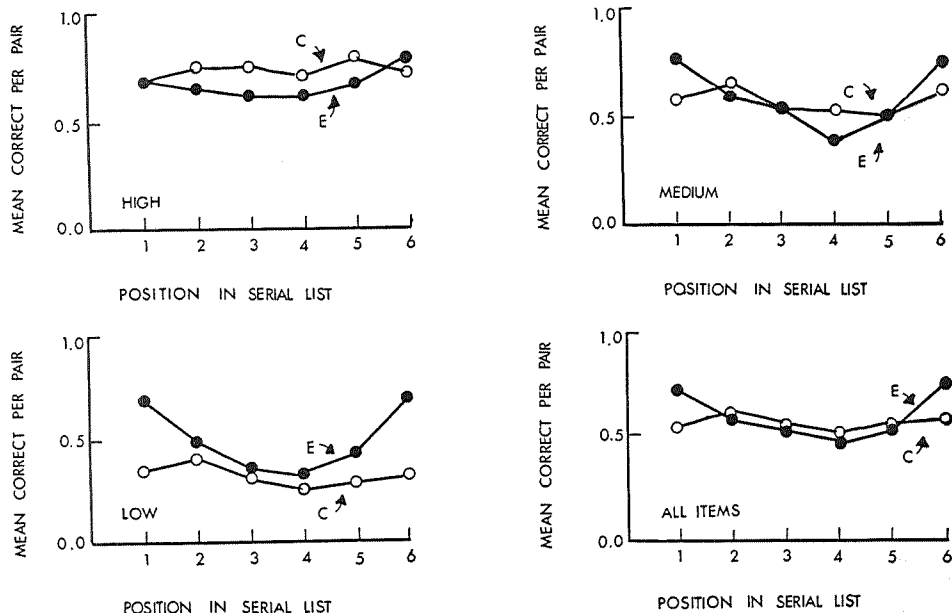

FIG. 2. Mean correct per pair for serial position by E/C pair combinations at each frequency level and across frequency levels on Trials 1–5.

TABLE 2

TRAINING BY E/C PAIR COMBINATIONS FOR
FIXED TRIALS AND TRIALS TO
THE 6/6 CRITERION

Training level	Fixed trials		Trials to criterion	
	E pairs	C pairs	E pairs	C pairs
50%	.52	.50	5.19	4.99
100%	.59	.58	4.31	3.53
150%	.63	.53	4.20	4.06

Fig. 2. It is evident from inspection of Fig. 2 that the bowed effect referred to earlier is attributable to performance on the experimental pairs. Similar findings have been reported by Stark (1968).

A subsequent examination of this interaction at each frequency level presents an even more striking contrast. These results are also shown in Fig. 2. For L materials, the interaction was significant, F (5, 225) = 4.92, $p < .01$, with the quadratic component accounting for 96% of the variance. Every E pair was superior to every C pair and the trend across positions for E pairs was decidedly curvilinear, while across positions for C pairs an essentially linear trend obtained. For intermediate frequency materials, a similar trend was found. Again the interaction was significant, F (5, 225) = 4.54, $p < .01$, and the quadratic component accounted for 83% of the variance. Thus, the pattern for L and M materials was strikingly similar except for the fact that no significant transfer on E vs. C pairs was obtained with M items. In both cases, the trend across positions was irregular, but essentially linear for C pairs and systematically bowed for E pairs. For H materials, the interaction was not significant, F (5, 225) = 1.74, although the trend for E pairs was slightly curvilinear, with no irregularities, while the trend for C pairs appeared to be linear with irregular fluctuations. In this case, the quadratic component accounted for 62% of the interaction variance. In general then, the overall pattern of results for the Position × E-C pairs interaction, despite discrepancies in sign and statistical significance of the E vs. C transfer effect, clearly suggests an influence of prior serial learning upon subsequent PA learning.

Training and transfer.—In the fixed-trials analysis, degree of training on the serial list failed to produce a significant effect, F (2, 135) = 2.51, and training did not interact significantly with the frequency variable, F (4, 135) = 1.90. However, these findings are not directly related to the question of whether or not transfer occurred as a function of these variables, since that measure depends on a comparison of E and C pairs.

The data relevant to the Training × E-C Pairs interaction are presented in Table 2. Although the interaction was significant at the .05 level, F (2, 135) = 3.07, it can be seen in Table 2 that the differences were quite small. In addition, subsequent analyses failed to confirm this interaction at any frequency level. The F ratios were less than unity for L and H materials and the value obtained for M materials, F (2, 45) = 2.41, fell far short of that required for statistical significance. It thus appears that whatever is responsible for the transfer effects obtained in the present study is not influenced by degree of training on the serial lists.

In both of the trials-to-criterion analyses, the training variable produced a significant main effect, Fs (2, 135) ≤ 6.02, and interacted significantly with frequency, Fs (4, 135) ≤ 3.75. However, in neither case did training interact significantly with E-C pairs, Fs (2, 135) ≤ 2.08. As the data in Table 2 indicate, it is probable that whatever training effects did occur were primarily attributable to the poor performance of Ss trained to the 50% criterion on L materials. Thus, the trials-to-criterion analyses also failed to suggest any influence of training on transfer.

Trials and transfer.—Naturally, the main effect of trials was significant, F (4, 540) = 369.64. However, the only interactions involving trials to attain significance were the Trials × E-C Pairs interaction, F (4, 540) = 7.08, $p < .001$, and the Trials × E-C Pairs × Position interaction, F (20, 2,700) = 2.90, $p < .005$. These effects simply reflect a decrease in the advantage for E pairs over trials and a flattening of the bowed pattern for E pairs.

No serial learning.—As indicated in the Method section, a fourth group of Ss was run at each frequency level on the PA lists. Since these Ss had no serial training, their performance in PA learning could only be compared to the C pairs for the other groups. The means for these groups are also shown in Fig. 1 and have been adjusted for differences in the number of pairs involved (6 vs. 12). It can be seen that the difference between the curve for C pairs and no serial learning was roughly constant at all frequency levels. At each frequency level the difference was significant. These differences cannot be attributed to response learning, since none of these items were presented to any S prior to PA learning. It could be argued that response learning for E pair items would reduce the total response learning for those Ss learning both E and C pairs. However, this interpretation suggests that a Frequency Level × Performance interaction would obtain and such a trend is clearly not reflected by the data. Of course, the fact that Ss without prior serial training learned lists of homogeneously unfamiliar items makes any interpretation somewhat tenuous.

DISCUSSION

The major hypotheses which have been offered to explain serial learning and subsequent transfer are the "chaining" hypothesis and the "ordinal position" hypothesis. Since both of these views—as well as variations of them (cf. Young, 1968)—involve associative explanations, it is somewhat perplexing to find that degree of serial training, and hence associative strength, failed to influence E vs. C performance in the transfer task (see also Young, 1962). Perhaps the most reasonable interpretation of this outcome is to consider the extent to which other mechanisms, compatible with association theory, can be employed to explain the major results. First, the bowed performance curves for E pairs could be explained on the basis of differential response integration (or familiarization)—even though the frequency of item exposure was constant—since the pattern of correct responding in serial learning matched the pattern found in transfer. Second, since the advantage of response familiarization would be expected to decrease with increases in item frequency,

this factor could also explain the decrease in transfer at higher frequency levels, although it is difficult to see how the response familiarization concept could account for the negative transfer obtained at the highest frequency level. Third, it is possible that response integration skills, an important component of learning-to-learn (LTL) effects, increase directly with prior serial training and transfer to the PA task. This would explain the performance differences on C pairs between Ss with and without prior serial training, as well as the main effect of the training manipulation.

The major results not explained by differential response familiarization and simple LTL effects are the negative transfer obtained with H materials and the absence of a Training × Transfer interaction. It should be noted with respect to the lack of interaction that the response integration explanation previously used to account for the bowed effect in transfer also requires that there be an effect of degree of serial training on transfer. This follows because the pattern of correct responding covaries with the number of serial acquisition trials, as well as with serial position. Of course, it could be argued that response integration effects are maximal in the early trials, therefore masking training effects, but then the effect of training on both E and C pairs requires explanation. Such apparent contradictions make it necessary to consider complex, and somewhat subtle, interactions that may obtain between LTL effects and interitem interference in transfer studies (cf. Postman, Keppel, & Zacks, 1968) in order to attempt a complete account of these discrepant results. One possibility is that interitem interference—resulting from the fact that the same class of materials was employed in both the serial and PA tasks (cf. Postman et al., 1968)—increases as a function of both training and frequency, thus offsetting the positive effects of LTL skills within a given frequency level and eliminating a Transfer × Training interaction. Provided that such LTL effects are greater than interitem interference with L materials, overall positive transfer would be expected. Conversely, if interitem interference increases as a function of frequency while LTL effects simultaneously decrease, overall negative transfer could be predicted at the highest frequency level. Thus, the variations in transfer shown in Fig. 1 are more or less comprehensible, as is the failure to find transfer covarying with degree of training, if one assumes that a delicate balance exists between positive and nega-

tive transfer mechanisms both of which increase with training and which are negatively correlated with each other across frequency levels.

While the preceding explanation is not inconsistent with contemporary accounts of LTL effects during transfer, it is an extremely complicated one which involves a number of rather tenuous assumptions concerning the balance of positive and negative transfer effects. There is also the problem that the use of interitem interference as an explanatory mechanism leads to ambiguities with respect to the expected direction of transfer with H materials. That is, if the unit-sequence hypothesis (Underwood & Postman, 1960) is invoked, it might be predicted that Ss learning H materials during the *serial* task would suffer, and have to overcome, more interitem interference than Ss learning lower frequency materials. Therefore, these Ss would have more specific practice in overcoming such interference prior to the transfer task. Thus, positive, not negative, transfer might be expected since both the response integration skills and those involved in dealing with interitem interference would be facilitative. Alternatively, transfer might still be expected at the higher frequencies if unit-sequence interference during the transfer task is greatest for the H materials, as would be assumed under the chaining hypothesis (see also Underwood, 1963). However, this possibility is inconsistent with the failure to find a Training × Transfer interaction, in that unit-sequence effects are associative effects and, therefore, should be sensitive to variations in serial training.

In addition to the contradictions inherent in the alternative explanations outlined earlier, most seem to beg the question of experimentally prescribed associations, or lack of them, in associative accounts of serial learning and transfer. In view of these difficulties, an explanation in which the observed transfer is viewed in terms of the *utilization of serially acquired information*, rather than an explicitly associative explanation, may turn out to offer a more parsimonious and powerful theoretical account.

One such explanation involves the assumption that items from a serial list are stored in memory in an ordered fashion, but that they do not automatically elicit one another as a chain of associates except in a very specialized sense. That is, in the context of the experiment and under experimental instructions, when S is given one item, he tends to produce the next item in the series.

In accord with this "search" hypothesis, if S is presented with a transfer task composed of the items involved in a prior serial task, he *may* actively search his memory of the list—especially if he is given appropriate instructions (cf. Postman & Stark, 1967; Stark, 1968) or if he has ample time to "run through" the serial list (cf. Heaps, Greene, & Cheney, 1968)—and apply that information to the performance requirements of the transfer task. It may be seen, then, that unlike strict associative accounts which would seem to require that performance on pairs in the transfer task continue to improve with degree of serial training, the "search" hypothesis adds the necessary qualifier that such continued improvement will be reflected in performance only to the degree that (*a*) S "recognizes" that the application of the serial information will be useful, (*b*) that the serial information is easily retrievable (e.g., items are well integrated and interference effects do not seriously impair retrieval), and (*c*) that S has ample time to search through his memory for the serial information. To the extent that these conditions do not obtain, little or no transfer may also result. Thus, the sign of transfer will depend upon a number of factors deriving both from serial learning and strategies that S employs during the transfer task.

Although it is clear that speculations of the sort offered here with respect to the "search" hypothesis are ad hoc and without direct experimental support, it seems appropriate at this point to indicate that the difficulties encountered in attempting to explain serial learning and subsequent transfer on a strictly associative basis have forced a consideration of other factors such as those suggested here.

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